12553/72 PATENT

UNITED STATES PATENT APPLICATION
FOR

SYSTEM AND METHOD FOR PREVENTING OPERATIONAL AND MANUFACTURING IMPERFECTIONS IN PIEZOELECTRIC MICRO-ACTUATORS

INVENTORS:

Ming Gao YAO
Masashi SHIRAISHI

PREPARED BY:

KENYON & KENYON

333 W. SAN CARLOS ST., SUITE 600
SAN JOSE, CALIFORNIA 95110

408-975-7500

Background Information

[0001] The present invention relates to magnetic hard disk drives. More specifically, the present invention relates to a system and method for preventing piezoelectric micro-actuator manufacturing and operational imperfections.

[0002] In the art today, different methods are utilized to improve recording density of hard disk drives. Figure 1 provides an illustration of a typical drive arm configured to read from and write to a magnetic hard disk. Typically, voice-coil motors (VCM) 102 are used for controlling a hard drive's arm 104 motion across a magnetic hard disk 106. Because of the inherent tolerance (dynamic play) that exists in the placement of a recording head 108 by a VCM 102 alone, micro-actuators 110 are now being utilized to 'fine-tune' head 108 placement, as is described in U.S. Patent Number 6,198,606. A VCM 102 is utilized for course adjustment and the micro-actuator then corrects the placement on a much smaller scale to compensate for the VCM's 102 (with the arm 104) tolerance. This enables a smaller recordable track width, increasing the 'tracks per inch' (TPI) value of the hard drive (increased drive density).

[0003] Figure 2 provides an illustration of a micro-actuator as used in the art. Typically, a slider 202 (containing a read/write magnetic head; not shown) is utilized for maintaining a prescribed flying height above the disk surface 106 (See figure 1). Micro-actuators may have flexible beams 204 connecting a support device 206 to a slider containment unit 208 enabling slider 202 motion independent of the drive arm 104 (See figure 1). An electromagnetic assembly or an electromagnetic / ferromagnetic assembly (not shown) may be utilized to provide minute adjustments in orientation/location of the slider/head 202 with respect to the arm 104 (See figure 1).

[0004] Utilizing actuation means such as piezoelectrics (see figure 3), problems such as electrical sparking and particulate-enabled shortage can exist. It is therefore desirable to have a system for component treatment that prevents the above-mentioned problems in addition to having other benefits.

Brief Description Of The Drawings

[0005] Figure 1 provides an illustration of a drive arm configured to read from and write to a magnetic hard disk as used in the art.

[0006] Figure 2 provides an illustration of a micro-actuator as used in the art.

[0007] Figure 3 provides an illustration of a 'U'-shaped micro-actuator utilizing multi-layered piezoelectric transducers (PZT) to provide slider actuation.

[0008] Figure 4 illustrates a potential problem of particulate-enabled shorting between piezoelectric layers.

[0009] Figure 5 illustrates various problems affecting PZT performance.

[0010] Figure 6 provides a cross-section of the micro-actuator arms with the micro-actuators unseparated and a cross-section of a micro-actuator arm after micro-actuator separation.

[0011] Figure 7 provides a cross-section of the micro-actuator arms with the micro-actuators unseparated and a cross-section of a micro-actuator arm after micro-actuator separation under principles of the present invention.

Detailed Description

[0012] Figure 3 provides an illustration of a 'U'-shaped micro-actuator utilizing multi-layered piezoelectric transducers (PZT) to provide slider actuation. A slider (not shown) is attached between two arms 302,304 of the micro-actuator 301 at two connection points 306,308. Layers 310 of PZT material, such as a piezoelectric ceramic material like lead zirconate titanate, are bonded to the outside of each arm (actuator finger) 302,304. PZT material has an anisotropic structure whereby the charge separation between the positive and negative ions provides for electric dipole behavior. When a potential is applied across a poled piezoelectric material, Weiss domains increase their alignment proportional to the voltage, resulting in structural deformation (i.e. regional expansion/contraction) of the PZT material. As the PZT structures 310 bend (in unison), the arms 302,304 (which are bonded to the PZT structures 310), bend also, causing the slider (not shown) to adjust its position in relation to the micro-actuator 301 (for magnetic head fine adjustments).

[0013] Figure 4 demonstrates a potential problem of particulate-enabled shorting between piezoelectric layers. During manufacture and/or drive operation, particles may be deposited, and particle(s) 404 may end up bridging conductive layers 406. Relative humidity can cause the particle(s) to absorb moisture from the air, enabling electrical conduction between PZT layers. This short 404 in the piezoelectric structure 406 can prevent its normal operation, adversely affecting micro-actuator 402 performance.

[0014] Figure 5 illustrates various problems affecting PZT performance. Figure 5a provides an image of a stray particle 504 bridging (and potentially shorting) piezoelectric layers 502. As stated above, humidity can cause the particle 504 to absorb moisture and become electrically conductive. Figure 5b provides an image of damage caused by electrical arcing 506

between piezoelectric layers 508. Under the right conditions of voltage and air humidity, electricity may arc between piezoelectric layers 508, causing damage and deformation 506. Figure 5c provides an image of 'smearing' 510 (and potentially shorting) between layers 512. Smearing can occur during manufacture when the micro-actuators are cut for separation. (See figures 6 and 7). Material of the different layers 512 is smeared across one another as the cutting tool passes over the surface exposed by cutting.

[0015] Figure 6 provides a cross-section of the micro-actuator arms with the micro-actuators unseparated and a cross-section of a micro-actuator arm after micro-actuator separation. Figure 6a illustrates a cross-section 604 of a portion 602 of a micro-actuator block structure. The cross-section 604 illustrates alternating layers 628 of conductive material 622 and PZT (insulating) material 624 applied to the micro-actuator. Figure 6b illustrates a cross-section 608 of a micro-actuator arm 606 after separating the micro-actuator 610 from others. Separation may be performed in one embodiment by mechanical means (e.g., a rotating wheel blade or a straight edge knife). Other embodiments involve electrical means for micro-actuator separation (e.g., electric sputtering or ion milling). Further, chemical means may be used (e.g., chemical vapor deposition (CVD)). Note that the sides of the micro-actuator arm (finger) 606 expose the piezoelectric layers, including the electrically-conductive layers 622.

[0016] Figure 7 provides a cross-section of the micro-actuator arms with the micro-actuators unseparated and a cross-section of a micro-actuator arm after micro-actuator separation and ending with conductive layer application under principles of the present invention. Figure 7a illustrates a cross-section 704 of a portion 702 of a micro-actuator block structure. Figure 7b illustrates a cross-section 708 of a micro-actuator arm 706 after separating the micro-actuator 710 from others. In one embodiment of the present invention, after a set of conductive strips

(conductive material) 712, such as gold, platinum or copper, are placed upon the micro-actuator arm 706, a PZT layer (insulative layer) 714 is applied over and between the conductive strips 712, physically and electrically isolating the conductive strips 712. Another set of conductive strips 712 and a PZT layer 714 are applied and the process is repeated until the number of layers and/or thickness is appropriate for the micro-actuator's application and performance. In one embodiment, the last layer applied is the conductive strip 712, followed by the placement of a bonding pad 716 upon the piezoelectric layers (and on opposite ends 717 of the micro-actuator finger 706, see also figure 9). In one embodiment, four to six layers PZT layers are utilized (five to seven conductive layers).

[0017] In one embodiment, upon separation of the micro-actuators 710, the PZT layers 714 physically isolate the conductive strips 712 from each other, and thus, prevent 'smearing' (and potential shorting). Further, the PZT layers 714 electrically insulate the sides of the piezoelectric layers, preventing 'arcing' damage and particulate contamination (electrical bridging/shorting).

[0018] Figure 8 provides a cross-section of the micro-actuator arms with the micro-actuators unseparated and a cross-section of a micro-actuator arm after micro-actuator separation and ending with PZT layer application under principles of the present invention. Figure 8a illustrates a cross-section 804 of a portion 802 of a micro-actuator block structure. Figure 8b illustrates a cross-section 808 of a micro-actuator arm 806 after separating the micro-actuator 810 from others. In one embodiment of the present invention, after a set of conductive strips (conductive material) 812, such as gold, platinum or copper, are placed upon the micro-actuator arm 806, a PZT layer (insulative layer) 814 is applied over and between the conductive strips 812, physically and electrically isolating the conductive strips 812. Another set of conductive

strips 812 and a PZT layer 814 are applied and the process is repeated until the number of layers and/or thickness is appropriate for the micro-actuator's application and performance. In one embodiment, the last layer applied is a PZT layer 815. In one embodiment, the last PZT layer 815 provides a 'window' (gap in insulation) for the bonding pad 816 to be attached within. (See figure 8). In one embodiment, four to six PZT layers and four to six conductive layers are utilized.

[0019] In one embodiment, upon separation of the micro-actuators 810, the PZT layers 814,815 physically isolate the conductive strips 812 from each other, and thus, prevent 'smearing' (and potential shorting). Further, the PZT layers 814,815 electrically insulate the sides of the piezoelectric layers, preventing 'arcing' damage and particulate contamination (electrical bridging/shorting).

[0020] Figure 9 provides a cross-section of a finger of a micro-actuator under principles of the present invention. In an embodiment, a window 902 is provided in the last PZT layer of 915 to give a conduction path between the top conductive layer (strip) 904 and the bonding pad 906.

[0021] Although several embodiments are specifically illustrated and described herein, it will be appreciated that modifications and variations of the present invention are covered by the above teachings and within the purview of the appended claims without departing from the spirit and intended scope of the invention.